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(54) **Title**: A SURFACE LIGHT SOURCE DEVICE

(57) **Abstract**: It is an objective of the present invention to provide a surface light source device that improves the efficiency obtained from a tubular light source and is easy to be manufactured as well as achieves uniform brightness. The surface light source device comprises a light guiding plate 4; a tubular light source 1 arranged in one side edge of the light guiding plate 4; a light source reflection mirror 2 arranged around the tubular light source 1; a reflection hologram 30; and a back reflection mirror 6. The area density of the diffraction grating of reflection hologram 30 increases as the distance from the light source 1 increases.

CLAIMS:

1. A surface light source device, comprising at least a translucent light guiding plate that planarly illuminates an object of illumination from behind and a tubular light source arranged in one side edge of said light guiding plate, said light guiding plate comprising: an edge entrance surface that receives incoming light from said tubular light source at said one side edge; a back reflection plane that reflects internal backward light forward at a back plane; and front emission plane that emits forth an internal light toward said object of illumination,

wherein said back reflection plane or said front emission plane of said light guiding plate comprises a hologram to diffract light from said tubular light source and said hologram is a hologram with area density of diffraction gratings that changes in proportion to the quantity of light that arrives from said tubular light source.

2. A surface light source device according to Claim 1, wherein said hologram is a reflection hologram that is arranged in said back reflection plane and area density of diffraction gratings of said hologram is increased as the distance from said tubular light source increases.

3. A surface light source device according to Claim 1, wherein said hologram is a reflection hologram that is arranged in said front reflection plane and area density of diffraction gratings of said hologram is decreased as the distance from said tubular light source increases.

4. A surface light source device according to Claim 1, wherein said hologram is a transmission hologram that is arranged in said front reflection plane and area density of diffraction gratings of said hologram is increased as the distance from said tubular light source increases.

5. A surface light source device according to Claims 1 through 4, wherein said hologram has a diffusion function.

6. A surface light source device according to Claims 1 through 5, wherein the diffracted wavelength of said hologram is approximated to the brightline spectra of the tubular light source.

7. A surface light source device according to Claims 1 through 6, wherein the diffracted wavelength of said hologram is approximated to red, green, blue lines of the brightline spectra of the tubular light source.

8. A surface light source device according to Claims 1 through 7, wherein the efficiency of said hologram is changed by the intensity of the brightline spectra of the tubular light source.

9. A surface light source device according to Claims 1 through 8, wherein area density of diffraction gratings of said hologram is changed by the intensity of the brightline spectra of the tubular light source.

TITLE OF THE INVENTION
A surface light source device

BACKGROUND OF THE INVENTION

[0001] FIELD OF THE INVENTION

The present invention relates to a surface light source device, specifically to a surface light source used as back light for liquid crystal display devices and the like.

[0002] PRIOR ART

Recently, liquid crystal display devices are widely used, specifically, direct-view-type liquid crystal display devices in which a surface light source device is used as a back light on the back side of a liquid crystal display device.
Although the requirements for those surface light source devices are varied depending on their application, specifically for personal laptop computers, the thinness, lightness, power saving, and brightness uniformity, etc., are required.

[0003] On one hand, there are various types of surface light source devices; however, they can be largely divided into two types: a type called an internal lighting or direct lighting type, in which the light source is located inside of the lighting plane; and a type called an edge lighting type, in which the light source is located outside of the lighting plane, and a tubular light source such as a fluorescent lamp (most of which is a cold-cathode tube) is closely attached to one edge or two edges of the light guiding plate consisting of a transparent acrylic resin plate or the like that is the lighting plane, whereby light is introduced into the light guiding plate via the side edge(s) of the light guiding plate.

[0004] Personal laptop computers specifically require thinness and lightness; therefore the edge lighting type is largely applied to these computers.
The primary functions required for the light guiding plate in the edge lighting type is the function to send the light that entered through the side edge forward and the function to emit the sent light towards the liquid crystal display device.
The former function is determined depending on the materials used for the light guiding plate and their surface reflection characteristics, and the latter function is determined depending on the shape of the surface of the light guiding plate and its ability to prevent a total reflection condition. As a solution to form the aforementioned shape, wherein the surface of the light guiding plate prevents the total reflection condition, formation of white diffusion material on the surface of the light guiding plate, surface roughening, or formation of Fresnel shape lenticulars or prisms on the surface of the light guiding plate are known.

[0005] The configuration of a surface light source device is exemplified as shown in Fig.7. In Fig.7, 1 indicates a tubular light source; 2 indicates a light source reflection mirror; 4 indicates a light guiding plate; 5 indicates a roughened surface of an emission

plane that is the front plane of the light guiding plate; and 6 indicates a back reflection mirror affixed to a reflection plane that is the back plane of the light guiding plate 4.

[0006] In Fig.7, out of the light from the tubular light source 1, the light radiated toward the light guiding plate 4 can arrive directly at the edge entrance plane of the light guiding plate 4, and the light emitted outward from the light source 1 hits and is reflected at the light source reflection mirror 2, and a part of it arrives at the edge entrance plane of the light guiding plate 4. Then, the light that arrives at the edge entrance plane can be somewhat refracted and enter into the light guiding plate 4.

[0007] Out of the light that entered into the light guiding plate 4, the light refracted relatively backward arrives at the back reflection plane. Then the light that arrives at the portion relatively close to the tubular light source 1 of the back reflection plane is reflected at the back reflection mirror 6 and travels within the light guiding plate 4 and then arrives at the front emission plane. At this time, the incidence angle of the light to this plane is smaller than the critical angle; therefore the light is refracted and emitted forward. The light that arrives at the portion far from the tubular light source 1 of the back reflection plane is reflected at the back reflection mirror 6 and travels within the light guiding plate 4 and then arrives at the front emission plane; however, the light emitted forward is weakened because the incident angle is larger than the critical angle.

[0008] Moreover, out of the light that entered into the light guiding plate 4 via the edge entrance plane, the light refracted relatively forward travels directly toward the front emission plane, and at the area relatively close to the tubular light source 1, the incidence angle is smaller than the critical angle, therefore the light is refracted and emitted forward; however, at the area far from the tubular light source 1, the incidence angle to the front emission plane is larger than the critical angle, therefore the light is totally reflected at the front emission plane and is thereby prevented from emitting forward.

[0009] Thus, unless any processing is performed on the front emission plane that is the front plane of the light guiding plate 4, when the incidence angle is smaller than the critical angle, the light will be emitted outward, and when the incident angle is lager than the critical angle, the light will not be emitted outward; therefore, usually, one portion in the light guiding plate 4 that is close to the tubular light source 1 becomes bright, resulting in uneven brightness. Therefore, surface roughening 5 may be performed on the front emission plane so that the light can be emitted forward. Moreover, prisms may be applied to increase the intensity of the light emitted forward, and a diffusion seat may be applied to create a more uniform surface light source.

[0010] Furthermore, surface roughening may be performed on the side of the reflection plane (back reflection mirror) 6 that is the back plane of the light guiding plate 4, and the reflection plane 6 may be inclined in order to make a curved surface, etc..

[0011] **PROBLEM(S) THAT THE PRESENT INVENTION INTENDS TO SOLVE**

With such a conventional configuration, in order to make the brightness in the surface light source device uniform, it is necessary to make the light travel to the portion away from the tubular light source 1 by subjecting the light from the tubular light source 1 to repeated total reflection within the light guiding plate 4, as well as to design the shape or a method of roughening the surface of the reflection plane 6 so that the quantity of the light on the display surface becomes even by such repeated total reflection within the light guiding plate 4.

[0012] However, roughening the reflection plane 6 can cause a decrease in the light transmittance. Moreover, inclining the shape of the reflection plane 6 to be e.g. a curved plane can cause problems in that it prevents thinness and, due to the complexity of the shape, necessitates a design for keeping the shape, in addition to the problem of the difficulty in designing the shape of the reflection plane 6. Due to these circumstances, the light efficiency has been greatly lowered.

[0013] On the other hand, the "edge illumination" method, in which the hologram is affixed to the light guiding plate and is reproduced with the light illuminated via the edge of the plate, is known (refer to e.g. Kubota, Fujioka, Kitagawa and Oka, "Compact device for producing holograms", the 21st Image Engineering Conference 12-8, pp. 247-250 (1990)), and the inventors of this invention considered applying this method to the surface light source device. However, for illumination in the surface light source device, a tubular light source is generally used, which has high monochromaticity, no parallel illumination, and no spatial room. Therefore, it turned out that it was difficult to make the hologram for the best surface light source device with a tubular light source, as well as difficult to control the efficiency of the hologram within the plane, and difficult to design, expose, and make a hologram corresponding to many kinds of surface light source devices.

[0014] This invention takes into account the aforementioned problems, and the object of the invention is to provide a surface light source that improves the efficiency obtained from a tubular light source, is easily manufactured, and achieves uniform brightness as well.

[0015] **SOLUTION TO SOLVE THE PROBLEM(S)**

This invention solves the aforementioned problems, and provides a surface light source device, comprising at least:

a translucent light guiding plate that planarly illuminates an object of illumination from behind; and

a tubular light source arranged in one side edge of said light guiding plate, said light guiding plate comprising: an edge entrance surface that receives incoming light from said tubular light source at said one side edge; a back reflection plane that reflects internal backward light forward at a back plane; and front emission plane that emits forth an internal light toward said object of illumination, wherein said back reflection plane or said front emission plane of said light guiding plate comprises a hologram to diffract light from said tubular light source and said hologram is a hologram with area

density of diffraction gratings that changes in proportion to the quantity of light that arrives from said tubular light source.

[0016] In this invention, a hologram to diffract light from the tubular light source is provided in the back reflection plane or the front emission plane of the light guiding plate, and this hologram is a hologram with an area density of diffraction gratings that changes in proportion to the quantity of light that arrives from said tubular light source; therefore the quantity of the light emitted from the front emission plane can be increased by changing the area density of the diffraction gratings corresponding to decreases in the quantity of the light that arrives from the tubular light source, and when the quantity of the light that arrives from the tubular light source is large, the quantity of the light emitted from the front emission plane can be decreased by changing the area density of the diffraction gratings accordingly, and the decreased portion of the light can be allocated to other areas where the quantity of the light arriving from the tubular light source is small, thereby, increasing the quantity of the light and as a result, allowing the light that entered into the edge entrance plane from the tubular light source to be emitted forward efficiently and uniformly in a plane.

[0017] Thus, light from the tubular light source can be emitted to the front plane relatively uniformly only by providing a hologram in the back reflection plane or the front emission plane of the light guiding plate by e.g. affixing it, and, therefore, the brightness uniformity of the lighting surface and the efficiency of light usage can be improved.

[00018] Moreover, in this invention, the quantity of the light diffracted at the hologram is changed by changing the area density of the diffraction gratings formed on the hologram. Furthermore, the area density of these diffraction gratings can be easily changed. This is because the area density of the diffraction gratings can be changed merely by changing the area density of the recording material on which the hologram is recorded before the exposure of the hologram, using a given photomask with ultraviolet rays etc.

[00019] It is preferred to use photopolymers as the recording material of the hologram from the perspective of durability etc. Moreover, a large amount of holograms used in the invention can be prepared at a low price by copying it.

[0020] When the hologram is a reflection hologram that is provided on the back reflection plane, by arranging the area density of the diffraction gratings of the hologram so that it increases as the distance from the tubular light source increases, the light that is generally decreased as it comes out from the tubular light source can be emitted forth more efficiently and uniformly in a plane.

[0021] When the hologram is a reflection hologram that is provided on the front reflection plane, by arranging the area density of the diffraction gratings of the hologram so that it decreases as the distance from the tubular light source increases, the light that is generally decreased as it comes out from the tubular light source can be emitted forth more efficiently and uniformly in a plane.

[0022] When the hologram is a transmission hologram that is provided on the front reflection plane, by arranging the area density of the diffraction gratings of the hologram so that it increases as the distance from the tubular light source increases, the light that is generally decreased as it comes out from the tubular light source can be emitted forth more efficiently and uniformly in a plane.

[0023] It is preferable that the aforementioned hologram has a diffusion function.

[0024] Moreover, it is preferable that the diffracted wavelength of the hologram is approximated to the brightline spectra of the tubular light source.

[0025] Furthermore, it is preferable that the diffracted wavelength of the hologram is approximated to red, green, and blue lines of the brightline spectra of the tubular light source.

[0026] It is also preferable that the efficiency of the hologram is changed by the intensity of the brightline spectra of the tubular light source.

[0027] It is also preferable that the area density of diffraction gratings of the hologram is changed by the intensity of the brightline spectra of the tubular light source.

[0028] **DESCRIPTION OF THE PREFERRED EMBODIMENTS**

EMBODIMENT 1

A side view of the surface light source device of the first embodiment of the invention is shown in Fig.1. As shown in Fig.1, the surface light source device in this embodiment comprises: a translucent light guiding plate 4 that illuminates planarly a liquid crystal panel (not shown in the figure) that is an object of illumination from behind; a tubular light source 1 that is arranged in one side edge of said light guiding plate 4; a light source reflection mirror 2 that is arranged around said tubular light source 1 and reflects the light scattered from the tubular light source 1 towards the light guiding plate 4; a hologram 30; and a back reflection mirror 6.

[0029] A plate 160mm x 220mm in dimensions and 10mm in thickness made from polymethyl methacrylate (PMMA, and refractive index: 1.49) is used for said light guiding plate 4, and the tubular light guiding plate 1 is attached to one narrow side of the side edge as shown in Fig.1. A hot cathode fluorescent tube (HCFT) of 8mm in diameter is used for the tubular light source 1 and a mirror surface film on which aluminum was deposited was used for said light source reflection mirror 2.
A cold cathode fluorescent tube (CCFT) hot cathode fluorescent tube (HCFT) may be used instead for the tubular light source 1.

[0030] Then the hologram 30 was affixed to the back reflection plane. A Lippman-type volume phase reflection hologram of 20 μm in thickness made from acrylic photopolymers is used for the hologram 30.

[0031] When hologram 30 was made, the mask shown in Fig.2 made beforehand was closely placed on a photosensitive material that is a photopolymer, and was exposed beforehand to ultraviolet rays. The configuration of the mask used in this embodiment as shown Fig.2 was as follows: the light guiding plate 4 was divided into 4 regions in a longitudinal direction, and the region closer to the tubular light source 1, where the quantity of light is larger, is defined as a white portion (UV transmitting portion), and the area of white portion (UV transmitting portion) is decreased as the distance from the tubular light source 1 increases. The photopolymer portion corresponding to the UV transmitting portion in this mask (white portion in Fig.2) is exposed to ultraviolet rays preliminarily before the exposure for making the hologram, therefore the diffraction gratings are not recorded in this UV transmitting portion. Therefore, the area in which the diffraction gratings are formed does not exist in the closest region to the tubular light source 1, and the area in which the diffraction gratings are formed increases as the distance from the tubular light source 1 increases, and thus the area density of diffraction gratings are formed in the same pattern as the mask pattern in Fig.2.

[0032] After the preliminary exposure with ultraviolet rays using the mask shown in Fig.2, a Lippman-type reflection hologram was prepared using two luminous fluxes of three-color coaxial lasers: argon laser, krypton laser, and dye lasers, as a light source.

[0033] With regard to the hologram 30, peak diffracted wavelengths are 613nm, 547nm and 539nm, with half width and efficiency being 25nm and 70% respectively for each, and the incidence angle and diffraction angle including the light guiding plate 4 being 60 degrees and 0 degrees, respectively. These peak diffracted wavelengths are determined from the measurement result of the brightline spectra from the hot cathode fluorescent tube (HCFT) used in this embodiment, and approximated to the brightline spectra. In the exposure of the hologram 30, in which the reference beam and the object beam are both parallel light, the diffusivity was given to the hologram 30 by using transmitted light through glass with a grain size of # 600 on both sides, for the object light.

[0034] In Fig.1, from among the light from the tubular light source 1, the light radiated toward the light guiding plate 4 can arrive directly at the edge entrance plane of the light guiding plate 4, and the light emitted outward from the light source 1 hits and is reflected at the light source reflection mirror 2, and a part of it arrives at the edge entrance plane of the light guiding plate 4. Then the light that arrives at the edge entrance plane can be somewhat refracted and enter into the light guiding plate 4.

[0035] From among the light that entered into the light guiding plate 4, the light refracted relatively backward arrives at the back reflection plane. Within this light, the light that arrives at a portion relatively close to the tubular light source 1 in the back reflection plane, where the diffraction gratings are not formed on the hologram 30, is transmitted through the hologram 30 and reflected at the back reflection mirror 6, and then travels within the light guiding plate 4 to the front reflection plane. At this time, the incidence angle of the light to this plane is smaller than the critical angle, therefore the light is refracted and emitted forward. The light that arrives at a portion in the back reflection plane far from the tubular light source 1, where the diffraction gratings are

formed, and also satisfies the diffraction condition, i.e. the light that entered from the direction of the tubular light source 1 at the incidence angle of 60 degrees, is diffracted in a zero-degree direction, i.e. the direction normal to the front emission plane, and then it travels within the light guiding plate 4 to the front emission plane. In this case, the incidence angle of the light that arrives at the front emission plane is smaller than the critical angle, therefore the light is emitted forth. The light that arrives at a portion in the back reflection plane far from the tubular light source 1, where the diffraction gratings are not formed, is reflected at the back reflection mirror 6 and travels within the light guiding plate 4 to the front emission plane, and if its incidence angle is smaller than the critical angle then the light is emitted forth, and if its incidence angle is larger than the critical angle then the light is not emitted forth.

[0036] Moreover, from among the light that entered into the light guiding plate 4, the light refracted relatively forward travels directly towards the front emission plane. In the region relatively close to the tubular light source 1, the incidence angle to the front emission plane is smaller than the critical angle, thereby allowing the light to be refracted and emitted forth; however, in the region relatively far from the tubular light source 1, the incidence angle to the front emission plane is larger than the critical angle, thereby causing the light to be totally reflected at the front emission plane and travel within the light guiding plate 4 to the back reflection plane. Then, similarly to the above, the light that arrives at a portion in the hologram 30 where the diffraction gratings are formed and also satisfies the diffraction condition, i.e. the light that entered at the incidence angle of 60 degrees, is diffracted in a zero-degree direction, i.e. the direction normal to the front emission plane, and again it travels within the light guiding plate 4 to the front emission plane, thereby allowing the light to be emitted forth. On the other hand, the light that arrives at a portion of the hologram 30, where the diffraction gratings are not formed, is transmitted through the hologram 30 and reflected at the back reflection mirror 6, and then travels within the light guiding plate 4 to the front reflection plane; however, the light that is emitted forth is weakened because its incidence angle is larger than the critical angle.

[0037] Thus, at a portion in the hologram 30 where the diffraction gratings are not formed, the light that is emitted forth is more weakened as the distance from the tubular light source 1 increases; however, the area of the diffraction gratings of the hologram 30 in this embodiment is graduated using the mask so that the area is increased as the distance from the tubular light source 1 increases, therefore the quantity of light that is diffracted at the diffraction gratings in the hologram 30, travels to the front emission plane and then is emitted forth is increased as the distance from the tubular light source 1 increases. Therefore, not only can the quantity of light that travels within the light guiding plate 4 to the front emission plane and is emitted forth be more uniform, but also light emission efficiency can be improved.

[0038] **EMBODIMENT 2**
A side view of the surface light source device of the second embodiment of the invention is shown in Fig.3. As shown in the Fig.3, similarly to the first embodiment, this surface light source device is provided with the light guiding plate 4, the tubular

light source 1, the light source reflection mirror 2, and the back reflection mirror 6 described in Embodiment 1.

[0039] A hologram 31 was affixed to the front reflection plane. The hologram 31 is a Lippman-type volume phase reflection hologram with a thickness of 20μm made from the same material to that in Embodiment 1.

[0040] And similarly to Embodiment 1, when the hologram 31 was made, the mask shown in Fig.4 made beforehand was closely placed on a photosensitive material that is a photopolymer, and was exposed beforehand to ultraviolet rays. The configuration of the mask used in this embodiment as shown Fig.4 was as follows: the light guiding plate 4 was divided into 4 regions in a longitudinal direction, and the region closer to the tubular light source 1, where the quantity of light is larger, is defined as a black portion (UV non-transmitting portion), and the area of black portion (UV non-transmitting portion) is decreased as the distance from the tubular light source 1 increases. Similarly to Embodiment 1, no diffraction grating is recorded on the photopolymer portion corresponding to the UV transmitting portion in this mask (white portion in Fig.4). Therefore, the diffraction gratings are formed on the whole part of the closest region to the tubular light source 1, and the area in which the diffraction gratings are formed decreases as the distance from the tubular light source 1 increases, and thus the area density of diffraction gratings are formed in the same pattern as the mask pattern in Fig.4.

[0041] After the preliminary exposure with ultraviolet rays using the mask shown in Fig.4, the hologram 31 was prepared with a similar exposure method to that in Embodiment 1, where the incidence angle and the diffraction angle encompassing the light guiding plate 4 were set to 60 degrees and 40 degrees respectively.

[0042] In Fig.3, from among the light from the tubular light source 1, the light radiated toward the light guiding plate 4 can arrive directly at the edge entrance plane of the light guiding plate 4, and the light emitted outward from the light source 1 hits and is reflected at the light source reflection mirror 2, and a part of it arrives at the edge entrance plane of the light guiding plate 4. Then the light that arrives at the edge entrance plane can be somewhat refracted and enter into the light guiding plate 4.

[0043] From among the light that entered into the light guiding plate 4, the light refracted relatively backward arrives at the back reflection plane. Then it is reflected at the back reflection mirror 6 and travels within the light guiding plate 4, then arrives at the front emission plane. Within this light, the light that arrives at a portion in the hologram 31 where the diffraction gratings are formed and also satisfies the diffraction condition, is diffracted; however, at a portion where the diffraction gratings are not formed, the light that entered at an incidence angle smaller than the critical angle is refracted and emitted forth, and the light that entered at an incidence angle larger than the critical angle is reflected at the front emission plane and travels within the light guiding plate 4.

[0044] In this embodiment, at a portion of the hologram 31 where the diffraction gratings are formed, the light that entered at 60 degrees from the direction of the tubular light source 1 is diffracted to a 40-degree direction and travels again through the region far from the tubular light source 1 towards the back reflection plane, and arrives at the back reflection plane. The light that arrives at the back reflection plane is reflected at the back reflection mirror 6 and travels within the light guiding plate 4, then arrives at the front emission plane. Independent of whether or not it is in the diffraction region in the hologram 31 affixed to the front emission plane, the light enters at a diffraction angle smaller than the critical angle and does not satisfy the diffraction condition of the hologram 31, and is therefore refracted and emitted forth.

[0045] Moreover, from among the light that entered into the light guiding plate 4 through the edge entrance plane, the light that was refracted relatively forward travels directly towards the front reflection plane, and similarly to the light reflected at the back reflection mirror 6 as shown above, the light that arrives at a portion in the hologram 31 where the reflection gratings are formed and also satisfies the diffraction condition is diffracted; however, at a portion in the hologram where the diffraction gratings are not formed, the light that enters at an incidence angle smaller than the critical angle is refracted and emitted forth, and the light that enters at an incidence angle larger than the critical angle is reflected and travels within the light guiding plate 4.

[0046] On the hologram 31, the area of the diffraction gratings is graduated using the mask as described above so that the area is increased as the distance from the tubular light source 1 increases, therefore, not only can the quantity of light that is emitted from the front reflection plane be more uniform within the light guiding plate 4, but also light emission efficiency of the front emission plane can be improved.

[0047] **EMBODIMENT 3**
A side view of the surface light source device of the third embodiment of the invention is shown in Fig.5. As shown in Fig.5, similarly to the first embodiment, this surface light source device is provided with the light guiding plate 4, the tubular light source 1, the light source reflection mirror 2, and the back reflection mirror 6 described in Embodiment 1.

[0048] Then the hologram 32 was affixed to the front reflection plane. The hologram 32 is a Lippman-type volume phase reflection hologram with a thickness of 20μm made from the same material to that in Embodiment 1.

[0049] And similarly to Embodiment 1, when the hologram 32 was made, the mask shown in Fig.6 made beforehand was closely placed on a photosensitive material that is a photopolymer, and was exposed beforehand to ultraviolet rays. The configuration of the mask used in this embodiment as shown Fig.6 was as follows: the light guiding plate 4 was divided into 4 regions in a longitudinal direction, and the region closer to the tubular light source 1, where the quantity of light is larger, is defined as a white portion (UV transmitting portion), and the area of white portion (UV transmitting portion) is decreased as the distance from the tubular light source 1 increases. Similarly to Embodiment 1, no diffraction grating is recorded on the photopolymer portion

corresponding to the UV transmitting portion in this mask (white portion in Fig.6). Therefore, no diffraction grating is formed in the closest region to the tubular light source 1, and the area in which the diffraction gratings are formed increases as the distance from the tubular light source 1 increases, and thus the area density of diffraction gratings are formed in the same pattern as the mask pattern in Fig.6.

[0050] After the preliminary exposure with ultraviolet rays using the mask shown in Fig.6, a transmission hologram was prepared with the same exposure method as that in Embodiment 1 except that the two luminous fluxes were radiated to one side of the photosensitive material. At this time, the incidence angle and the diffraction angle encompassing the light guiding plate 4 were set to 30 degrees and 0 degrees respectively on the hologram 32.

[0051] In Fig.5, from among the light from the tubular light source 1, the light radiated toward the light guiding plate 4 can arrive directly at the edge entrance plane of the light guiding plate 4, and the light emitted outward from the light source 1 hits and is reflected at the light source reflection mirror 2, and a part of it arrives at the edge entrance plane of the light guiding plate 4. Then the light that arrives at the edge entrance plane can be somewhat refracted and enter into the light guiding plate 4.

[0052] From among the light that entered into the light guiding plate 4, the light refracted relatively backward arrives at the back reflection plane. Then it is reflected at the back reflection mirror 6, travels within the light guiding plate 4, and arrives at the front emission plane. Within this light, the light that arrives at a portion in aforementioned hologram 32 where the diffraction gratings are formed and also satisfies the diffraction condition, i.e. the light that entered from the direction of the tubular light source 1 at the incidence angle of 30 degrees, is emitted in a zero-degree direction, i.e. from the front emission plane. As for the light in the region where the diffraction gratings on the aforementioned hologram 32 affixed to the front emission plane are not formed, the light that enters at a diffraction angle smaller than the critical angle is refracted and emitted forth, and the light that enters at a diffraction angle larger than the critical angle is reflected and travels within the light guiding plate 4.

[0053] Moreover, from among the light that entered into the light guiding plate 4 through the edge entrance plane, the light that was refracted relatively forward travels directly towards the front reflection plane, and, similarly to the light reflected at the back reflection mirror 6 as shown above, the light that arrives at a portion in the hologram 32 where the reflection gratings are formed and also satisfies the diffraction condition is refracted and emitted from the front emission plane; however, at a portion in the hologram where the diffraction gratings are not formed, the light that enters at an incidence angle smaller than the critical angle is refracted and emitted forth, and the light that enters at an incidence angle larger than the critical angle is reflected and travels within the light guiding plate 4.

[0054] The area of the diffraction gratings of the hologram 32 is graduated using the mask as described above so that the area is increased as the distance from the tubular light source 1 increases, therefore the quantity of light that is diffracted by the

diffraction gratings in the hologram 32 travels to the front emission plane and then is emitted forth is increased as the distance from the tubular light source 1 increases. Therefore, not only can the quantity of the light that is emitted from the front emission plane be more uniform within the light guiding plate 4, but also light emission efficiency can be improved.

[0055] The surface light source devices in Embodiments 1, 2, and 3 are merely examples, and they may be used in combination, or a plurality of the tubular light source 1 may be used so that the light can enter through a plurality of edges of the light guiding plate 4, and accordingly the holograms 30, 31 and 32 may be modified. Moreover, holograms 30, 31, and 32 may be modified if the tube diameter of tubular light source 1 and the thickness of the light guiding plate 4, etc., are changed.

[0056] For hologram materials in the aforementioned embodiments, besides well-known hologram photosensitive materials such as photopolymers of polyvinylcarbazole etc. or dichromated gelatin, additionally, a dichromated gelatin, optical resists, silver salts etc. can be used, and for the holograms, volume phase holograms of Lippman-type etc. are preferable in terms of obtaining high diffraction efficiency. Moreover, not limiting to holograms recorded using two luminous interferences, computer generated holograms (CGHs), which are prepared by calculating and drawing desired hologram interference patterns using computers, may also be used.

[0057] In the aforementioned embodiments, the holograms were exposed through three-color, coaxial multiple exposure; however, the holograms may be provided with different optical diffraction functions or patterns for each color, or multiple holograms that have different optical diffraction functions, or patterns may be layered.

[0058] Moreover, it is also possible to change the diffracted wavelength according to the kind and wavelength characteristics of back light; thus this invention is not limited to these embodiments, and various modifications are possible.

[0059] Thus an excellent surface light source device with less nonuniform brightness can be obtained by changing the area of the diffraction portion in the hologram corresponding to the region. Conversely, it is also possible to increase or decrease the brightness at the specific region by causing nonuniform brightness intentionally. In these embodiments, the hologram was divided into 4 regions, but naturally, finer control of nonuniformity of the brightness is possible by dividing into more regions. For instance, by crosswise control as well as longitudinal control, it is possible to deal with nonuniform brightness derived from the tubular light source, and the surface light source device with a shortened tubular light source, a point light source or multiple light sources can be made. The position of the light source can be set more freely because of decreased nonuniform brightness. Moreover, if the area of the diffraction portion in the hologram is graduated continuously, the hologram becomes seamless, and the difference in brightness between regions can be made negligible.

[0060] Furthermore, besides polyethyl methacrylate (PMMA), glass, polycarbonate, polyurethane, polystyrene, etc., can also be used for the light guiding plate 4, and preferably they are light and highly transparent.

[0061] As is clear from the above description, using a surface light source device of the invention, comprising at least a translucent light guiding plate that planarly illuminates an object of illumination from behind and a tubular light source arranged in one side edge of said light guiding plate, said light guiding plate comprising: an edge entrance surface that receives incoming light from said tubular light source at said one side edge; a back reflection plane that reflects internal backward light forward at a back plane; and a front emission plane that emits forth an internal light towards said object of illumination, a hologram to diffract light from said tubular light source that is provided in said back reflection plane or said front emission plane of said light guiding plate, and said hologram being a hologram with area density of diffraction gratings that changes in proportion to the quantity of light that arrives from said tubular light source, the quantity of light emitted from the front emission plane can be increased by changing the area density of the diffraction gratings corresponding to a decrease in the quantity of light that arrives from the tubular light source, and when the quantity of light that arrives from the tubular light source is large, the quantity of light emitted from the front emission plane can be decreased by changing the area density of the diffraction gratings accordingly, and the decreased portion of the light can be allocated to other areas where the quantity of light arriving from the tubular light source is small, thereby increasing the quantity of light, and as a result, the light that entered into the edge entrance plane from the tubular light source can be emitted forward efficiently and relatively uniformly in a plane.

[0062] Thus, light from the tubular light source can be emitted to the front plane relatively uniformly only by providing a hologram in the back reflection plane or the front emission plane of the light guiding plate by e.g. affixing it, and the brightness uniformity of the lighting surface and the efficiency of the light usage can be improved.

[0063] Moreover, it is easy to make these holograms that have changed area density of the diffraction gratings.

[0064] The surface light source device of the invention can be applied for various displays, not limited to the liquid crystal display device.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 shows a side view of the surface light source device of the first embodiment of the invention.
Fig.2 shows a plan view of the mask used for preparation of the hologram used for the surface light source device of the first embodiment of the invention shown in Fig.1.
Fig.3 shows a side view of the surface light source device of the second embodiment of the invention.
Fig.4 shows a plan view of the mask used for preparation of the hologram used for the surface light source device of the second embodiment of the invention shown in Fig.2.

Fig.5 shows a side view of the surface light source device of the third embodiment of the invention.
Fig.6 shows a plan view of the mask used for preparation of the hologram used for the surface light source device of the third embodiment of the invention shown in Fig.5.
Fig.7 shows a side view of a conventional surface light source device.

Explanation of Signs
1: a tubular light source, 2: light source reflection mirror 30, 31, 32: a hologram, 4: a light guiding plate, 5: emission plane, 6: a back reflection mirror.